PARTICULATE SCATTERING

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LONG TERM GOAL

My long-term goal is to contribute to our understanding of the influence of the inherent optical properties on apparent optical properties.

SCIENTIFIC OBJECTIVES

I would like to understand radiative properties of class 2 waters. In particular I concentrate on 4-component system composed of phytoplankton, CDOM, water, and submerged bubble clouds. I calculate remote sensing reflectance, asymptotic distribution of the diffuse light, and bi-directional reflectance.

APPROACH

I employed radiative transfer code HYDROLIGHT to study remote sensing reflectance. The inherent optical properties of bubbles were calculated using the Mie solution. Maps of global distribution of bubbles were calculated from NCAR/NCEP global winds.

WORK COMPLETED

Work on remote sensing reflectance is completed and summarized below. I report on the influence of bubble clouds generated by breaking waves on the remote sensing reflectance and calculate not only inherent optical but also apparent optical properties using radiative transfer model. It is shown that the optical effects of bubbles on remote sensing of the ocean color are significant. Furthermore, global maps of volume fraction of air in water are presented. These maps, together with the parameterization of the microphysical properties, show the climatological significance of bubble clouds on the global albedo of incoming solar energy. By proxy, I show the influence of the bubble clouds on the remote sensing retrieval of organic and inorganic components of the natural waters.

It is worth mentioning that the bubble clouds coincide with the upper range of the euphotic zone and will therefore contribute to the dynamics of the upper-ocean boundary layer, heat distribution, and sea surface temperature. In fact initial motivation for this work was an observation by (Zaneveld, 1997, private communication) that the asymptotic radiance distribution is being established close to the ocean surface in apparent contradiction with theoretical studies.

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RESULTS

There is evidence that at high wind speeds, separate bubble clouds near the surface coalesce, producing a stratus layer with deeper clouds reaching below.

We have calculated the normalized phase function for submerged bubbles and compared it with the Petzold phase function for a uniform distribution of bubbles between size parameter 100 and 300 and refractive index n=3/4.

The reference model runs were performed with the 3 component system of phytoplankton, pure water, and DOM with a constant chlorophyll profile. Two cases (not presented) were computed representative of clear coastal and oceanic water. The remote-sensing reflectance for the 3 component system composed of water, DOM, and particulates (no microbubbles) and for the 4 component system (microbubbles included) was calculated for the same chlorophyll concentration in both cases. Hydrolight model with 62 layers, maximum depth 50m, maximum bubble depth 8m, 35 wavenumbers between 400-700nm, sun zenith angle 50 was used.

Performance of the pigment algorithms based on the ratio of reflectances will depend on the ratio of reflectances r1/r2. Submerged microbubble clouds seem to be wavelength selective and even the ratio algorithms may require slight systematic correction. Given the increased sensitivity of the current generation of ocean color instruments, the absolute value of the radiances at the top of the atmosphere can be used for pigment retrievals. In such a case effect of the microbubbles may be of great importance.

IMPACT/APPLICATION

Our calculations indicate that the optical effect of submerged microbubbles on the remote sensing reflectance of the ocean color may be significant. These results are of importance for the retrievals of pigments from the ocean color measurements and for studies of the energetics of the ocean mixed layer. We provide information of how to reduce the systematic error due to microbubbles in pigment retrievals schemes based on reflectance ratio.

On the other hand much remains to be done. There are several assumptions here that may be questioned. For example, more information about the effective radius and the volume fraction is needed. The effective radius is a semi-inherent optical property because it carries information not only about the size itself but also about orientation of particles, their morphology, coating, size distribution, and departure from a spherical shape; we need more information about microbubble radiative radius. It is interesting to note that stabilized, coated microbubbles are hypothesized to be correlated to phytoplankton and CDOM concentrations; we need parameterization of this process. The optical properties of the first several meters below the surface are difficult to measure and are often removed from the data due to experimental problems such as ship shadow or wave activity. This is the region where more detailed studies are needed.

TRANSITIONS

N/A

RELATED PROJECTS

N/A

REFERENCES

Remote-sensing reflectance of bubble clouds in seawater, Flatau, P. J., M. K. Flatau, J. R. V. Zaneveld, C. D. Mobley, 1997, submitted to J. Gephys. Res. Oceans.

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